Relationship between estimated finishing-pig space allowance and in-transit loss in a retrospective survey of 3 packing plants in Ontario in 2003

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Abstract

The objective of this study was to determine the association between space allowance and in-transit loss of finishing pigs going to select abattoirs in Ontario during summer weather conditions. The study included data from 2- or 3-tiered trailers transporting ≥ 130 pigs in June, July, and August 2003 to 3 packers that processed 76% of Ontario market pigs. Daily in-transit loss data were merged with packer data to determine the number of pigs on each trailer. Space allowance (in square meters per pig) was estimated from the percentage of each trailer's capacity that was filled by the load size. Actual pig weights were not available. Hourly temperature and relative humidity were obtained from 2 local Ontario weather stations. In-transit loss increased with environmental temperature, by 6.6 times at temperatures between 28°C and 34.2°C compared with < 17°C. At space allowances between 0.44 and 0.43 m^2/pig compared with ≥ 0.515 m^2/pig, in-transit losses increased 2.12 times when environmental temperatures were < 21°C. Temperature is likely a more important determinant of in-transit loss than space allowance. However, in-transit losses in hot weather are likely to be reduced by increasing space allowance or by adding a cooling device.

Résumé

L'objectif de la présente étude était de déterminer l'association entre l'allocation d'espace et les pertes en transit de porcs en finition dirigés à des abattoirs sélectionnés en Ontario durant les conditions climatiques estivales. L'étude incluait des données provenant de remorques à 2 ou 3 paliers transportant ≥ 130 porcs durant les mois de juin, juillet et août 2003 à 3 grossistes en viande qui transformaient 76 % des porcs de marché ontariens. Les pertes quotidiennes en transit étaient combinées avec les données des grossistes en viande afin de déterminer le nombre de porcs dans chaque remorque. L'allocation d'espace (en mètres carrés par porc) était estimée à partir du pourcentage de la capacité de chaque remorque qui était remplie par la taille du chargement. Le poids actuel des porcs n'étaient pas disponible. Les données horaires de température et d'humidité relative ont été obtenues de deux stations météorologiques ontariennes locales. Les pertes en transit ont augmenté avec les températures environnantes par un facteur de 6,6 à des températures entre 28 et 34,2 °C comparativement à des températures < 17 °C. En comparant des allocations d'espace de 0,44 et 0,43 m^2/porc à des valeurs ≥ 0,515 m^2/porc, les pertes en transit augmentèrent par un facteur de 2,12 lorsque les températures environnantes étaient < 21 °C. La température est probablement un déterminant plus important de pertes en transit que l'allocation d'espace. Toutefois, il est possible de réduire les pertes en transit lors de températures chaudes en augmentant l'allocation d'espace ou en ajoutant un dispositif de refroidissement.

(Traduit par Docteur Serge Messier)

Introduction

In-transit loss is a term used to describe pigs that die after leaving the farm but before being processed by the packing plant. In the past 10 y, this mortality rate has ranged from 0.08% to 0.15% of finishing pigs shipped in different areas of the world, including Canada (1–3). Previous research from Europe found the following factors associated with in-transit death: high environmental temperature and relative humidity, high stocking density (or low space allowance), and very short or very long journey (1,4–28). Thermal stress is generally the greatest contributor to in-transit loss (1,4,18,27,29). However, stocking density or space allowance on the trailer, measured as pigs per square meter, square meters per pig, or kilograms per square meter, appears to interact with high external temperature in predicting in-transit loss, because higher stocking densities decrease the ability of pigs to dissipate metabolic heat via convection: there is less space for air to flow between the pigs (1,15,17–19,30–33). High stocking density alone can increase numbers of in-transit deaths for pigs (1). The in-transit mortality rate tends to decrease from 0.27 to 0.08 when space allowance (transport floor space) increases from 0.39 to 0.48 m^2/pig for 129-kg market-weight pigs (34). Increased load size is also correlated positively with increased rates of in-transit death (16).

In Ontario, information on load size is recorded by transporting companies, packers, and the Ontario Pork Producers Marketing Board (OPPMB) through individual truck manifests but is not

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collected in databases containing information on in-transit loss. In general, it is difficult to determine the range of densities or numbers of pigs on trailers transporting market pigs in Ontario. Therefore, it is unknown whether transport companies comply with recommendations of space allowance and whether these space allowances are associated with in-transit losses. The purpose of this study was to determine if there was an association between space allowance and in-transit loss of finishing pigs in shipments to 3 packers during summer weather conditions.

Materials and methods

In-transit loss data describing the pigs shipped by each producer for each day in 2003 were provided by the OPPMB. Each observation, representing the group of pigs marketed by a producer on a given day, included date of shipment, producer's identification number (producer), number of pigs shipped by that producer that day, number of pigs in the group that died in transit, trucking company (transporter), packing plant (packer), and expected time of arrival at the packer. Three Ontario packers processed 76% of Ontario market pigs in the years 2001 to 2003. Records pertaining to shipments to these 3 packers during the months of June, July, and August 2003 were extracted from the full in-transit loss dataset.

The receiving records obtained from each participating packer listed the number of pigs received from the transporter each day and the date when the load was received. Data from 1 packer also included the time when the pigs were unloaded. Packer data were merged with OPPMB in-transit loss data to determine the number of pigs on each trailer.

The number of pigs on a trailer was further validated if, according to packer data, it seemed likely that a transport company had more than 1 truck arriving at the plant at the same time (e.g., if > 250 pigs were received by 1 packer from 1 transport company at 1 time). Also, if, according to packer data, a truck appeared to deliver some pigs to 1 packer and the rest to another packer (e.g., the receiving records of each plant indicated that there were small loads of < 180 pigs on a trailer) those records were further scrutinized to arrive at truck load size. Number of pigs per load was also validated by means of either the transport company dispatch record or the hard copy of the OPPMB manifest (a manifest is written each time a trucker picks up pigs at a farm). Of all the pigs marketed to the 3 participating packers during these 3 mo, 82% were transported on loads validated by these methods. No further validation was possible owing to budget constraints. This study was limited to pigs transported on 2- or 3-tiered trailers 48 to 53 ft long. Loads with < 130 pigs were removed from the current analyses since we could not determine whether a smaller truck was used or whether a large truck was used that was not full. The final data set represented 77% of pigs shipped to the 3 participating packers during the summer of 2003.

In a study by Haley (35), individual compartment areas were measured on nine 3-tier trailers, and results showed that the area available for pigs was dependent on 3 increments of load size: < 150 pigs, 150 to 179 pigs, and ≥ 180 pigs. For trailers 48 to 53 ft long, the percentages of total trailer area available at these 3 increments were 72%, 95%, and 100%. These increments were based on the way the trailer was loaded. For example, if there were 165 pigs in a load, the top-most compartment at the back remained empty. Space-allowance measurements were determined from the trailer-use percentages. Trailer sizes were obtained from a separate OPPMB database for each transporter. If the transporter was among the 7% that provided dispatch logs, the exact size of each trailer used for each load of pigs was known. For other transporters having trailers of more than 1 size, a weighted average of total trailer area was calculated. The size of the areas used was divided by the number of pigs on a trailer to obtain space allowance, estimated in square meters per pig. The total weight of the pigs on each load was not available.

Hourly dry-bulb and wet-bulb temperature and relative humidity were obtained for the Ontario Climate Centre, Downsview, Ontario, for the 2 Ontario weather stations located geographically closest to the packers. Documentation regarding the format of the data and their appropriate units were found on Environment Canada's website (36). Weather data were merged with the in-transit loss data by expected hour of delivery of the pigs to the packer or the actual hour of arrival for packers with that information available.

Statistical analysis

The in-transit losses per producer per day were modeled with a negative binomial distribution. The number of pigs marketed by each producer each day was used as the denominator for calculation of the incidence death rate. Associations with in-transit loss ratios were determined for environmental temperature and humidity values and for stocking densities (in square meters per pig) individually in 2 series of models.

Hierarchical dummy variables were created for environmental temperature to identify specific threshold levels at which losses increased in the 1st series of models. In-transit loss was regressed on these variables, which were deleted by means of a backward selection process, with elimination one at a time on the basis of the highest P-value until all were significant at the 5% level (37). The incidence rate ratio produced by these models shows the increase in the in-transit losses at 1 temperature range compared with the temperature range immediately lower in the model. These incidence rates for the hierarchical variables are additive. Therefore, the sum of the incidence rates for all temperature ranges in the model compares the rate of losses in the highest temperature range to those at a temperature less than the lowest in the model. This temperature fixed-effect model was analyzed and tested for goodness of fit, outliers, and leverage with the use of STATA (Stata Corporation, College Station, Texas, USA).

Mixed models using the significant temperature fixed-effect models were created by adding producer and transporter as random effects. The mixed-models analyses were conducted with use of a Glimmex macro in SAS (SAS Institute, Cary, North Carolina, USA) that was based on a Poisson distribution with pigs transported per producer per day as the offset.

For the 2nd series of models, new data sets were created on the basis of specific temperature ranges that were subsets of the original data set. Selected ranges were based on the significant threshold levels of temperature identified in the 1st set of models and the frequency distribution of temperature during the study. These ranges were 5.7°C to 20.9°C (low), 21°C to 24.9°C (moderate), and 25°C to 34.2°C (hot). For each data set, hierarchical dummy variables were

Table I. Distribution of in-transit loss (mortality rate per pig marketed per producer per day) and environmental temperature for the percentiles of stocking density of market pigs shipped to the 3 largest Ontario packing plants in June through August 2003 in 3 temperature categories

Percentile	Stocking density (m^2/pig)	Average dry temperature (°C)	Mortality/pig marketed (%)
Temperature < 21°C			
0–9	0.338 to < 0.391	15.9	0.05
10–29	0.391 to < 0.413	17.2	0.18
30–49	0.413 to < 0.433	17.9	0.22
50–69	0.433 to < 0.459	17.8	0.26
70–89	0.459 to < 0.505	17.7	0.12
90–100	0.505 to ≤ 0.610	17.4	0.14
Temperature 21°C to 24.9°C			
0–9	0.362 to < 0.402	23.0	0.18
10–29	0.402 to < 0.427	23.3	0.29
30–49	0.427 to < 0.441	23.0	0.17
50–69	0.441 to < 0.461	23.0	0.24
70–89	0.461 to < 0.505	23.1	0.23
90–100	0.505 to ≤ 0.606	23.2	0.06
Temperature 25°C to 34.2°C			
0–9	0.370 to < 0.415	26.9	0.40
10–29	0.415 to < 0.433	27.4	0.37
30–49	0.433 to < 0.448	27.5	0.43
50–69	0.448 to < 0.465	27.3	0.47
70–89	0.465 to < 0.505	27.8	0.31
90–100	0.505 to ≤ 0.606	28.3	0.76

created (37). In-transit loss was regressed on these density dummy variables to identify those significantly associated with in-transit loss for each temperature range data set. The incidence rate used as the outcome in this model was a measurement of the number of pigs that died in transit that were shipped by a given producer divided by the number of pigs in that shipment that were owned by that producer for 1 space allowance level compared with the referent space allowance of ≥ 0.515 m^2/pig.

Results

This study included 728 087 pigs shipped by 2308 producers in 2041 loads through 68 transport companies to the 3 largest packing plants in Ontario during June to August 2003. The in-transit loss was 1593 pigs, or 21.9 pigs per 10 000 marketed. This represented 23% of all in-transit mortality in 2003 and 50% of in-transit mortality during these 3 mo in Ontario. Space allowance on the trailers in this study ranged from 0.61 to 0.34 m^2/pig or, assuming an average live weight of 114 kg, 0.54 to 0.30 m^2/100 kg.

Table I presents the distribution of in-transit loss and environmental temperature over the full range of stocking densities. The highest average stocking densities were observed when the average environmental temperatures were numerically lowest, and lower densities were observed at the higher temperatures. The maximum densities observed at low, moderate, and high temperatures were 0.338, 0.362, and 0.370 m^2/pig, respectively.

Table II. Association between in-transit loss[a] of the market pigs, temperature, and relative humidity

Fixed effect	IRR	$s_{\bar{x}}$	*P*-value
Intercept	0.00	0.20	< 0.001
Temperature 17°C to < 21°C	1.66	0.11	< 0.001
Temperature 21°C to < 25°C	1.41	0.08	< 0.001
Temperature 25°C to < 28°C	1.30	0.07	< 0.001
Temperature 28°C to 34.2°C	2.23	0.07	< 0.001
Humidity/10	1.04	0.02	0.04
Random effect	**Variation**	$s_{\bar{x}}$	*P*-value
Producer[b]	1.18	0.09	< 0.001
Transporter[b]	0.27	0.09	< 0.001
Error term	0.84	0.01	< 0.001

$s_{\bar{x}}$ — standard error of the mean.

[a] Measured as mortality rate for transported pigs per producer per day with the use of a negative binomial linear effects model. The association was measured as an incidence rate ratio (IRR) based on a Poisson general linear mixed model, with IRR indicating the number of times the incidence rate of in-transit death increased for a temperature range compared with the range below it. *N* = 13 590 pigs marketed.

[b] Included in the model as random variables.

The environmental temperature ranged from 5.7°C to 34.2°C during the study. In-transit losses increased with environmental temperature (Table II). The incidence rate ratio (IRR) indicates the number of times the incidence rate of in-transit death increased for a temperature range compared with the range below it. Specifically, thresholds of 17°C, 21°C, 25°C, and 28°C were each associated with incremental increases in in-transit losses. The in-transit losses increased 1.3 times at environmental temperatures of 25°C to 27°C compared with temperatures of 21°C to 24°C. These coefficients are additive; therefore, the in-transit loss at environmental temperatures of 28°C to 34.2°C was 6.6 times the loss at temperatures lower than 17°C when the effects of humidity, farm of origin, and transport company were controlled for. The farm of origin and transport company accounted for 52% and 11%, respectively, of the variation in in-transit loss not explained by temperature and humidity.

The temperature ranges associated with significant increases in in-transit losses were used to divide the data set into 3 subsets to assess the association between space allowance and in-transit loss. The temperature ranges of 5.7°C to 20.9°C, 21°C to 24.9°C, and 25°C to 34.2°C (36%, 31%, and 33% of the data set, respectively) represented mild, moderate, and hot weather in the summer of 2003 in Ontario. The IRR indicates the number of times the incidence rate of in-transit death increased for a space allowance range compared with the referent group (space allowance of ≥ 0.515 m^2/pig). In the lowest temperature range, in-transit losses increased 2.12 times at densities between 0.427 and 0.435 m^2/pig, inclusive, compared with densities of ≥ 0.515 m^2 per pig (Table III). At moderate temperatures, in-transit losses were higher at space allowance ranges starting at 0.513, 0.500, 0.465, 0.444, and 0.417 m^2/pig compared with densities of ≥ 0.515 m^2/pig. At the highest temperatures, in-transit losses at space allowance ranges starting at 0.465, 0.444, 0.435, and 0.408 m^2/pig differed from those at densities of ≥ 0.515 m^2/pig.

Table III. Association between in-transit loss[a] of the market pigs and stocking density on a trailer at various summer temperatures

	Temperature range (number of pigs)								
	Mild: 5.7°C to 20.9°C (4850)			Moderate: 21°C to 24.9°C (4162)			Hot: 25°C to 34.2°C (4578)		
Stocking density (m^2/pig)[b]	IRR	$s_{\bar{x}}$	*P*- value	IRR	$s_{\bar{x}}$	*P*- value	IRR	$s_{\bar{x}}$	*P*- value
≥ 0.503 to ≤ 0.513	NS	NS	NS	2.88	1.493	0.04	NS	NS	NS
≥ 0.490 to ≤ 0.500	NS	NS	NS	2.54	1.202	0.05	NS	NS	NS
≥ 0.457 to ≤ 0.465	NS	NS	NS	4.07	1.647	< 0.001	2.52	0.761	< 0.001
≥ 0.437 to ≤ 0.444	NS	NS	NS	2.54	1.014	0.02	1.97	0.600	0.02
≥ 0.427 to ≤ 0.435	2.12	0.800	0.05	NS	NS	NS	1.81	0.537	0.05
≥ 0.410 to ≤ 0.417	NS	NS	NS	2.58	1.097	0.03	NS	NS	NS
≥ 0.402 to ≤ 0.408	NS	NS	NS	NS	NS	NS	2.21	0.832	0.04

NS — Category not significantly different from the referent density.
[a] Within a temperature range the incidence death rate was approximately the IRR times the incidence death rate for pigs transported at the referent density.
[b] Each category was compared with the referent density of ≥ 0.515 m^2/pig.

Discussion

Density on a trailer affects a pig's ability to dissipate heat to maintain a relatively stable core body temperature. Each pig on the trailer produces its own heat and humidity as part of normal metabolic processes. A healthy market-weight pig generates 200 W and produces 0.05 g of water per second (38). As space allowance decreases, internal trailer temperature increases because more pigs are generating heat. Pigs are not able to dissipate heat through radiative or conductive means via a thermal gradient if there is physical contact with other pigs and they are forced to stand without contact with the trailer metal itself. Also, the pig's ability to cool using evaporation from mucosal surfaces is compromised because of a reduced vapor pressure gradient when humidity inside the trailer is high owing to the presence of other pigs (1,15,17–19,30–33).

In this study, in-transit losses tended to increase as space allowance decreased, particularly in higher environmental temperatures. The stocking densities at which in-transit losses increased significantly were dependent on temperature ranges. At low environmental temperatures, in-transit losses were 2.12 times higher at densities between 0.427 and 0.435 m^2/pig (2.30 and 2.34 pigs/m^2 or 262 to 267 kg/m^2 at an average shipping weight of 114 kg) than at densities ≥ 0.515 m^2/pig (≤ 1.95 pigs/m^2). This density range represents smaller loads than those recommended by the OPPMB (Irene Domanski: personal communication) for its lowest temperature range.

At moderate and high environmental temperatures, losses were significantly higher at several space allowance levels than at ≥ 0.515 m^2/pig. Specifically, for moderate temperatures, and for density ranges beginning at 0.513, 0.500, 0.465, 0.444, and 0.417 m^2/pig (1.95, 2.00, 2.15, 2.25, and 2.40 pigs/m^2), in-transit losses were higher than when the space allowance was ≥ 0.515 m^2/pig (≤ 1.95 pigs/m^2). Similarly, for high temperatures, and for density ranges beginning at 0.465, 0.444, 0.435, and 0.408 m^2/pig (2.15, 2.25, 2.30, and 2.45 pigs/m^2), in-transit losses were higher than when the space allowance was ≥ 0.515 m^2/pig (≤ 1.95 pigs/m^2). A 3-tier, 50-ft livestock transport trailer is expected to provide approximately 92 m^2 in available pig holding space when all compartments are used. Therefore, to provide sufficient space to reduce in-transit losses associated with densities of 0.457 to 0.465 m^2/pig (2.15 to 2.19 pigs/m^2) in moderate and hot summer weather in this study, the number of pigs shipped in these types of trailers would have to be limited to 198 and 202, respectively. This range of pig densities is lower than those recommended for moderate and high temperature ranges by the OPPMB (Irene Domanski: OPPMB, personal communication).

Recommendations for stocking density levels have been determined by other researchers (15–17,19,23,25,34). Many of these studies considered wider ranges of density and relied on descriptive analyses. When densities are > 2.5 pigs/m^2 (285 kg/m^2 at an average shipping weight of 114 kg, or 0.4 m^2/pig or 0.4 m^2/100 kg), there is an increase in average in-transit loss from 0.04% to 0.77% (1,31,32). Other trials have correlated higher densities with higher in-transit losses. Ritter et al (34) noted that in-transit loss trended lower by more than 70% when stocking density was reduced from approximately 2.5 to 2 pigs/m^2 (or 0.4 to 0.5 m^2/pig). Hamilton et al (16) also found that when controlling for an average stocking density of approximately 2.1 pigs/m^2, the number of pigs on a load was correlated with in-transit loss levels.

The results of Hamilton et al (16) imply that both stocking density and actual pig numbers impact in-transit losses. Ideally the welfare of transported pigs and the economic considerations of the producer, transporter, and packer should coincide. In this study, several ranges of stocking density were associated with higher in-transit losses. If the Ontario swine industry were to choose a range of 0.457 to 0.465 m^2/pig (2.15 to 2.19 pigs/m^2) for moderate and high temperatures, this would require a limit of 202 pigs on a 3-tier, 50-ft trailer, which is nearly the same as the current OPPMB recommended limit of 203 pigs in hot weather. The current cutoff of 2.33 pigs/m^2 (215 pigs per load) for moderate weather would likely reduce in-transit losses observed in the range of 0.437 to 0.444 m^2/pig (2.25 to 2.29 pigs/m^2) (Transporter Loading Chart, Ontario Pork, 2009, provided by Irene Domanski, OPPMB). However, a reduction to 0.49 m^2/pig (2.04 pigs/m^2) would possibly alleviate the in-transit losses observed at 0.457 to 0.465 m^2/pig (2.15 to 2.19 pigs/m^2) and would limit the pigs on a 3-tier, 50-ft trailer to 202.

The number of pigs on a trailer is determined directly by the transporter and producer and indirectly by the packer. The packer demands that pigs are marketed within a specific weight range. Most producers ship pigs once a week and insist that all pigs in a weight range be transported to the packer the same day. The transporter arranges to pick up pigs at 1 or more farms' sites according to the number of pigs the producer expects to have ready for market. If additional pigs reach the appropriate weight, the transporter's choices are to leave some pigs behind or make additional trips. Pigs left at the farm grow beyond the acceptable weight for the packer, and therefore the producer will lose money. However, the transporter is paid on a per-pig-delivered basis and must have a certain number of pigs on the trailer to cover his expenses. Although this study has identified ranges of densities associated with higher in-transit losses for the packers, transporting smaller numbers of pigs may not be economically justifiable for transporters. It may be necessary to legislate lower pig densities. Transporters may have the option of maintaining higher densities if they install cooling devices such as drip cooling or fans. Research in Europe has found that use of active ventilation (i.e., fans), particularly when vehicles are stationary, can extract warm and humid air that accumulates in the trailer (15,38).

Incremental increases in environmental temperature were associated with higher in-transit losses. Other researchers have found a correlation between average dry temperature during shipment and in-transit losses (1,4,7,16,18,21,23,31,33). The results of this study agree with those of Warriss and Brown (27), who found higher levels of in-transit loss associated with ambient temperatures > 16°C. However, other researchers argue that stocking density (or space allowance) of pigs, measured by the number of square meters per pig, the number of pigs per square meter, or the number of pigs on a trailer, is a more important predictor of in-transit loss than external temperature when internal trailer temperatures are kept within pigs' thermoneutral zone with an upper critical temperature — the environmental temperature beyond which pigs can no longer maintain a stable core temperature without external heat dissipation (29) — of 23°C to 31°C (16,25,29). When pigs are transported during the hot summer months, it is difficult to separate the impacts of space allowance and external temperature. This problem might be solved by combining the 2 factors; that is, by measuring internal temperatures. Increasing the stocking density on the trailer increases the internal trailer temperature because more pigs produce more heat (24,29). In this study, space allowance was not associated with in-transit loss when we placed environmental temperature and humidity with it in the models. Therefore, we conclude that temperature is a more important determinant of in-transit loss than space allowance or stocking density. However, density is expected to affect loss differentially according to temperature.

Perhaps more important than the effect of temperature or space allowance in transit upon in-transit loss is the effect upon in-transit loss imposed by the farm of origin. The producer, as a random effect, accounted for 52% of the in-transit loss not explained by temperature and humidity in this study. In a previous study that used the population data of these packing plants for a different year (2001), farm of origin of shipments accounted for 25% of the variation in in-transit loss not explained by a composite measure of temperature and humidity (35). Other research has noted farm health indicators (e.g., nonambulatory) indicative of arrival status at the plant via correlation (34). That study also did not find temperature measured inside the truck to be correlated with loss (nonambulatory or dead) at the plant, whereas trip factors such as total trip time were correlated with death. However, the study was limited to 1 "farm" in the sense that all shipments originated from 1 management company, and there may not have been enough management random (or latent) elements to tease out the variation due to sites of origin of the shipments. Farm as a random effect not only accounted for clustering and the lack of independence of observations in the current study but also the overall effect of things that were not measured for impact on in-transit loss, such as farm loading facility arrangements. A recent study determined that loading distance (home pen to loading ramp) had minimal effects on losses at the plant (nonambulatory or dead), as did season as a surrogate for temperature during shipment (39).

This study may have been limited by our estimation of space allowance, and transporters may have altered space allowance according to environmental temperature. Transporters in Ontario are asked to follow guidelines for space allowance on trailers in hot summer weather. Specifically, at temperatures > 24°C, it is recommended that transporters with 3-tier, 50-ft trailers limit the number of pigs to 203. The significant space allowance ranges in this study that were identified for moderate and high temperatures were likely driven, in part, by the fact that Ontario transporters were loading pigs at lower stocking densities in high temperatures compared with moderate and low temperatures. Therefore, lower stocking densities were identified as associated with losses at moderate temperatures. However, there is potential to reduce losses by further reducing density.

Of the 1.28 million pigs marketed in Ontario to all plants during the months of June through August 2003, this survey included 57%, or 728 087 pigs, representing 77% of all pigs marketed to the 3 largest Ontario packing plants during those 3 mo. The losses for the pigs in this study were 21.9/10 000; however, losses for the industry during this period ranged from 22.8/10 000 to 38.6/10 000 for each month. This discrepancy is likely due to the inclusion of only large trucks and the 3 largest Ontario packing plants; small trucks, smaller packers, and packers outside Ontario were excluded. Researchers in Europe have examined the association between stocking density and in-transit loss using sample sizes of 3888 to 232 000 pigs (1,16,19,26). In North America, studies of this type are rare, but a recent investigation into the effects of stocking density on the incidence of dead and nonambulatory pigs at 1 slaughter plant included 74 loads carrying 12 511 pigs (34). Another North American study used a smaller sample and was not an observational study (2).

Although this study does not represent pigs transported on small trailers or those transported to other packers, provinces, or countries, it does point out the limitation of the data currently being collected in the Ontario industry. If future studies were to examine the impact of space allowance on in-transit loss, the trailer size and the number of market pigs on each trailer must be consistently recorded. It is currently impossible to validate the number of market pigs on a trailer without accessing several sources of data, and for transporters providing more than 1 size of trailer the trailer size must be estimated.

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